Joint Analysis of Seismic and Electromagnetic Data from the New Jersey Continental Margin: An Expansion

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LONG-TERM GOALS

- To improve our understanding of the relationships between sedimentary physical properties and geophysical parameters.
- To establish methodologies for the joint interpretation of independent geophysical data sets.

OBJECTIVES

Ambiguity in interpretation of geophysical data in terms of seafloor physical properties can be reduced if independent and complementary data sets are examined together. However, opportunities to carry out such analyses are rare. A cruise completed in 1998 featured coincident measurements of electrical resistivity and shear wave velocity across a series of buried paleo-channels on the New Jersey continental shelf. We propose to combine analyses of these two independent measures of seafloor structure to provide greater insight into the nature of the channels both in terms of the infilling material and the contrast in physical properties across the channel walls.

APPROACH

A cruise carried out in September 1998 had two main objectives focussed around areas where buried paleo-channels had been seen previously in high resolution seismic reflection profiles. These objectives were to measure the 2-D and 3-D shear-wave velocity structure of the uppermost 50m of sediments across the channels and also to measure the electrical resistivity structure of the channels. It is well known that interpretations of a single physical parameter are subject to non-uniqueness. With resistivity for example, the conversion from resistivity to porosity requires assumptions to be made about the fluid distribution. The electrical resistivity of sediments is most commonly related to porosity by Archie's law. While we have seen reasonable agreement between porosity profiles inferred from resistivity and those measured in cores, combining measurements of two physical properties will greatly reduce the ambiguity by reducing the number of free parameters. This works as long as the two physical properties are sensitive to different aspects of the grain-fluid structure. While shear wave velocity also depends on sediment porosity, it also depends on the degree of coupling between the motion of the pore fluid and the sediment frame. This suggests that the measurements of electrical resistivity and seismic shear velocity that we plan to combine will be suitably independent. Both 2-D

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and 3-D interface-wave tomography experiments were carried out at two locations where buried channels are known to exist in the uppermost 5-10 m of the seabed. The on-bottom source generates directly vertically-polarized shear waves. The receivers were autonomously recording seismographs with three-component seismometers that record ground motion with high fidelity in the band 5-50 Hz. The EM experiment used the Canadian towed system used previously off northern California. We completed a total of 4 days of transmission including two regions of dense coverage in the same boxes where 3D The EM method used provides bulk porosity estimates to depths of around 20m below the seafloor and is thus able to place constraints on the nature of the channel infill and the contrast in physical properties across the channel boundaries. Our data show that a key condition for the channels to have an electrical signature is that they incise a regional unconformity, **R**, thought to represent a subaerially eroded surface, exposed during the late Wisconsinan glaciation. Channels that cut **R** are seen through increases in apparent porosity. Another seismically imaged channel sequence, which lies within the outer-shelf sediment wedge sequence above **R**, does not have an electrical signature. These channels appear to be carved in a surface arising from a less long-lived hiatus and result from erosion that need not have been subaerial, but might rather reflect a nearshore, deltaic or fan environment containing outflow channels.

An example of how resistivity and seismic data can be combined to predict fluid distributions is given in Evans (1994). In this case examining the relationship between resistivity and compressional wave velocity and comparing this relationship against combinations of empirical relationships allowed inference of the permeability structure of the oceanic crust. Our approach will be to similarly combine the distributions of electrical and shear wave velocities across the channels. Key properties we hope to resolve are the nature of the material infilling the channels and the contrast in physical properties across the channel walls.

WORK COMPLETED

The large amount of seismic data is currently being reduced: for example, shot and receiver locations are being determined. We are assembling a series of 1-D velocity-depth profiles to be use as starting models for a full 3-D inversion. We will use a well-tested inversion algorithm developed by Guust Nolet at Princeton. The code is running and we are in the process of modifying it for our application. The electrical resistivity data have been further analysed, resulting in a publication describing the channel structures from an electrical veiewpoint.

As a means of establishing methodologies of combining seismic and electrical data sets, several ODP logging profiles, in which co-located seismic, electrical and porosity information are available are under analysis.

RESULTS

The EM responses of the northern channels are consistent with structures about 7-10m deep with a high porosity unit a few meters thick lining their bases, possibly sands that have not compacted. These sands might be a nearshore sequence emplaced as sealevel rose. In general, clear EM channel signatures are seen where Milliman et al., (1990) show a minimal to zero thickness of late Quaternary sediment. While this is a necessary condition to see channels, it is not sufficient, as no channel signatures were seen along about 80% of line 3 which was run roughly parallel to the shelf break beginning to the southwest of the NSA, indicating that such structures are not ubiquitous but are rather confined to specific locations on the shelf.

The channel set within a southern region, which shows up so clearly in reflection profiling but not in EM imaging, must not have a substantial change in bulk properties between the channel infill and the channel base and walls. There may be a thin weathering surface that acts as a sufficient reflector of seismic energy but which is too thin too have an impact on the EM data. While the EM data indicate a gradient of porosity with depth, this is a normal signature of marine sediments reflecting depth dependent compaction. Thus, there is not necessarily a change in material deposited before and after formation of the channel. This would suggest that these channel sets formed during a fairly brief hiatus, after which this portion of the shelf was returned to a former but similar depositional environment.

IMPACT/APPLCATIONS

The establishing of methodologies for the joint interpretation of seismic and electrical properties will have ramifications for a wide variety of geophysical investigations. The importance of carrying out joint surveys has been noted in many situations and is not confined to those measuring sedimentary properties, but includes programs such as the MELT experiment, the largest seafloor geophysical survey undertaken measuring the properties of the mantle beneath a fast spreading midocean ridge.

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